APPENDIX D

Containment Barrier Design Memorandum

Black & Veatch
Philadelphia Office

DESIGN MEMORANDUM

To: Project File

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Proj. 47118.128

From: Gary Snyder

Subject: Metachem Barrier Wall Project

1.0 Problem Statement

The Interim Groundwater Remediation Program for the Metachem Site requires that groundwater flow be controlled to minimize the offsite migration of groundwater contamination and degradation of the surrounding surface waters of the Unnamed Tributary and the Red Lion Creek. Groundwater migration can best be controlled with some combination of partial containment and groundwater extraction. This design memorandum specifically addresses the issues associated with the construction of a partial barrier to groundwater flow and outlines the 30% design, Preliminary Design, elements and identifies future design requirements.

2.0 Design Objective

The barrier design objective is to provide a low permeability subsurface barrier to impede groundwater and aid hydraulic control by groundwater extraction. The barrier should be constructable within the various site constraints and compatible with the site contaminants. The design should provide for longevity of the barrier from physical and chemical attack. The barrier should be a cost competitive alternative.

3.0 Data Review

The 30% design included a review of the prior reports and available information for baseline design information, particularly for hydrogeological and geotechnical information. This data provides useful general information for extrapolating design data. Additional data may be required prior to completion of the design or prior to construction in order to provide added certainty to current design assumptions. Design data gaps and objectives are further discussed in later sections.

The Intermediate Design (CRA, 2001) was considered in this design to develop upon work by others. Several elements of this design have been incorporated into the proposed approach as it relates to the barrier. However, the groundwater extraction is assumed to be completed with extraction wells rather than with a trench drain as proposed by CRA. We see constructablity and cost issues associated with an extraction trench and adjacent barrier as opposed to a more typical barrier containment and extraction well system.

4.0 Conceptual Design

4.1 Criteria

The barrier design criteria are summarized in the table below:

Criteria	Value/Parameter	Remarks
Length	Impede flow; allow capture	Approx. 3,200 lf
Depth	> 2 ft key into Potomac	Approx. 35 ft
Width	> 2 ft	
Permeability	$< 1 \times 10^{-7}$ cm/sec	Based upon lab testing
Design Life	> 30 years	
Constructability	Conventional means & methods	
Operation & Maintenance	Minimal O&M requirements	

4.2 Barrier Type

The design considered several barrier types including earthen material and synthetic materials. Earthen material types include Soil Bentonite (SB) barriers and Soil Cement Bentonite (SCB) barriers. Synthetic materials considered the various rigid sheet pile (steel and plastic) types as well as the non-rigid (polyethylene) vertical containment systems installed with mandrels/frames and vibratory systems. Advantages and disadvantages exist for all options.

The general site surface and subsurface features would allow the installation of either earthen or driven/vibrated systems. Concern exists for barrier integrity (i.e. interlock separation and embedment) with driven or vibrated systems, given the nature of some of the more resistant granular soils. Some concern exists for the constructability issues associated with earthen barriers. However, at this stage of the design development, the earthen systems are deemed preferable based upon all the considered design criteria and are therefore being carried forward in the design process.

SB barriers are earthen barriers composed of a mixture of natural granular soils, natural plastic fines (clays) and added bentonite. The bentonite is added in liquid form as part of the slurry trenching process and mixed with the natural materials to achieve the desired backfill characteristics (i.e. slump and permeability) prior to placement back in slurry trench. Dry bentonite addition can also be used to augment the backfill and further control the permeability.

4.3 Alignment, Extent and Location

The barrier is designed to impede flow rather than contain groundwater and is therefore arranged perpendicular to, and concave in the direction of, flow to maximize the capture and minimize the contaminant migration to the adjacent surface water and marsh areas (See Drawing SB-2). The barrier extends approximately 3,200 lineal feet (lf) and extends to an average depth of 35 feet to key into the underlying clay member of the Potomac Formation. The location of the barrier shown on Drawing SB-2 attempts to maximize the hydraulic benefit and meet other site constraints such as property lines and constructablity issues. The West Reach of the barrier is located at the top of slope

because of soft soil and constructability issues of building in the lower marsh area and set back from the slope crest due to concerns for local and global slope failure during construction of the barrier. The North and East Reaches do not present the same steep slope issues of the West Reach and the barrier is located to maximize capture and along the contour to minimize preparatory earthwork to allow barrier construction.

4.4 Hydrogeologic Data and Groundwater Flow

Hydrogelogic information is presented in the prior reports and summarized on the provided preliminary drawings (Drawing SB-2 and SB-3). Flow direction is generally from the southeast to northwest. Simulations of the impact of the proposed barrier on groundwater flow are provided by the groundwater model results (Refer to Appendix A of the attached Preliminary Groundwater Design Report). In summary, the barrier impedes flow and causes groundwater mounding up-gradient of the wall. The mounding, resulting from the groundwater capture, will be controlled through groundwater extraction. Extracted groundwater will be collected and treated at the onsite treatment facility.

Additional geologic interpretation and confirmation will be performed as the design progresses to further define the stratigraphy, extent of the underlying clay layer and the general variability of the upper Columbia Formation.

4.5 Geotechnical Data

The successful design and construction of a barrier wall requires that geotechnical data be collected along the alignment of the barrier wall. Typical industry practice is to obtain closely spaced soil samples from the surface to the bottom of the wall, usually an impermeable layer which will establish a good key-in. Borings to collect these soil samples are typically drilled at 100- to 200-foot intervals along the alignment so that variability of soil horizons can be established. The tests that are completed on soil samples generally include gradation, Atterberg limits, unit weight and moisture content, and permeability of the key-in horizon.

Preliminary review of the geotechnical data reveals that some usable information is available. Further design will compile the data and define sensitivity to changes in geotechnical parameters and physical properties. Additional data collection may be recommended. For example, as the West Reach of the barrier approaches the steeper slopes, the design will likely require additional soil strength information to establish stability criteria

4.6 Barrier Design

4.6.1 Preparatory Earthwork and Working Platform

SB barrier construction requires a relatively level and stable working surface to enable construction utilizing the liquid slurry method. Typically, this is accommodated by trench alignment, earthwork, segmental construction methods or other means.

Future design will evaluate the earthwork requirements to establish a level working platform while minimizing cut and fill needs. The earthwork design will also include the

stability analysis of critical slopes, such as the West Reach, under future loading conditions (i.e. added soil load and live loads). The resulting design will lead to a proposed grading plan and section views of the working platform and final site grade.

4.6.2 Key-In Depth

An adequate key is often critical to minimize the overall containment leakage that may result from barrier underflow. Key depth must allow for seating the barrier in competent low permeability soil. The key must be deep enough to accommodate some buildup of soil that has settled out of suspension during the slurry construction process and was not removed from the excavation prior to backfilling, effectively acting as a sump. The depth of the key is usually 2 to 4 feet to ensure that proper key-in has occurred.

The clay of the Potomac Formation should not present excavation difficulty and should be easily identifiable in the field by digging resistance. This should allow for an accurately excavated key. It is estimated that the target key depth will be 3 feet.

4.6.3 Wall Thickness

The thickness of the wall usually varies from 2 to 4 feet to provide an adequate containment barrier under the typical conditions. The thickness is primarily a function of head differential across the barrier and concern for hydrofracture, contaminant transport, and practical limits of excavation equipment. Depending on the design objective, some sites can have a wall thickness less than 2 feet and others can have a wall thickness greater than 4 feet.

The hydraulic differential across the barrier will be managed by the groundwater extraction system. The depth of the proposed barrier is well within the depth range of typical excavators. Therefore the design will progress assuming a wall thickness of 2 feet.

4.6.4 Trench Stability Analysis

The stability of the trench is critical for successful wall construction. Stability concerns may arise with porous native soil, high water tables, long open trenches and excessive surcharge or construction loads. A stable trench prevents run-in of higher permeability material from the walls into the trench.

Further design will review the stability based upon a worst case scenario of maximum head differential during a period of high water table and low slurry trench level. Calculations will establish construction criteria to manage trench stability.

4.6.5 Backfill Permeability Testing

The permeability of backfill used to construct the barrier wall is a key design parameter, and should be adequately tested. References and sources vary greatly on what constitutes the standard practice. Pre-construction backfill mix design, permeant and testing procedures vary the number of required tests. However, the consensus average testing was approximately 3 tests of the same mix batch in order to average out laboratory and testing variability.

Future design will evaluate the geotechnical properties and empirical data to estimate permeability and backfill properties. The design will specify needed testing to either be performed as part of the design or immediately prior to construction. Testing will follow proven procedures for permeability testing in flex wall permeameters.

4.6.6 Trench Slurry Compatibility

The slurry used in the trench has to be compatible with the groundwater, and any contaminants present in the subsurface soils. Chemically active waters can inhibit bentonite hydration or flocculate the slurry, possibly causing trench instability during construction. Literature has shown that DNAPL, certain chlorinated hydrocarbons and salt water can adversely impact the slurry, trench sidewall cake, and the resulting backfill permeability.

Future design will look more closely at the range of contamination and concerns. If warranted, slurry compatibility testing will be recommended for completion prior to design submission.

4.6.7 Long-Term Backfill Compatibility

The backfill used in the trench should be compatible with the in-situ soils and groundwater. If concerns exist, compatibility tests are generally run using samples of the in-situ soil, groundwater, and proposed backfill materials. Typically, several permeability tests of multiple pore volumes are performed to simulate a long-term condition and identify degradation.

The backfill will either utilize excavated, and therefore recycled, soil or can utilize imported soil. It is less costly to recycle the backfill and augment with imported soil, only as required. The ROD for the Metachem Site specifies that all excavated materials must meet the off-site cleanup criteria before they can be used as backfill for the barrier. Future design will look at the material balance along the wall alignment and also look at the chemical compatibility and contaminant concentration. If warranted, slurry backfill compatibility testing, as described above, will be recommended for completion prior to design submission.

4.6.8 Barrier Penetration Details

Subsurface utilities can be present along the barrier wall alignment and these have to be delineated, rerouted, or protected with water tight connections as required.

Future design will consider any existing penetration and the possible need for penetration and protection for the proposed groundwater extraction system and other anticipated site improvements.

4.6.9 Surface Cap Details

The surface cap over the barrier wall alignment is required to protect against the long term physical disturbance of the barrier.

Future design will design the surface cap to provide adequate protection and allow for integrating a possible future site wide cap. In addition, the design will consider the need for traffic crossing at locations along the barrier and incorporate such as may be needed.

4.6.10 Protection from Desiccation

The proposed barrier materials are primarily clays and bentonite which are susceptible to desiccation, which can lead to the development of macroppores and secondary permeability in the upper section of the barrier.

The future design will assess this potential and consider mechanism to protect against desiccation if required.

4.6.11 Construction Sediment and Erosion Control

The flow of construction sediment from the vicinity of the trench into the trench can create permeable windows in the barrier wall. In addition, sediment and erosion of contaminated or even non-contaminated construction materials can adversely impact the adjacent water courses.

The future design will incorporate grading, drainage, and erosion controls to manage the transport of sediment and offer erosion control.

5.0 Proposed Plans

The design of the barrier will require approximately six drawings to adequately present the information for the construction contractor. The proposed drawings are outlined below.

Sheet	Title	Remarks
SB-1	Existing Conditions	Survey; site constraints; environmental conditions
SB-2	Barrier Alignment	Proposed grading; barrier locations; site improvements
SB-3	Barrier Section I	Grading; geology; excavation limits; geotechnical data
SB-4	Barrier Section II	Grading; geology; excavation limits; geotechnical data
SB-5	Barrier Details I	Earthwork detail; crossings; wells; other
SB-6	Barrier Details II	Earthwork detail; crossings; wells; other

Preliminary versions of Drawing SB-2 and SB-3 are provided in the Appendix F of the attached Preliminary Groundwater Design Report.

6.0 Proposed Specifications

Specifications for the barrier will be prepared consistent with industry standards and the remaining construction solicitation package. We anticipate seven specifications that will be unique to the barrier construction. These are outlined below:

- Section 1605-Sampling for Chemical Testing
- Section 1606-Materials Handling and Disposal

- Section 2200-Earthwork
- Section 2270-Erosion and Sediment Control
- Section 2395-Hydraulic Barrier
- Section 2396-Laboratory Testing for Hydraulic Barrier
- Section 2670-Boring and Well/Piezometer Installation

A preliminary version of Section 2395 is provided (for information purposes only) in Appendix A of this Design Memorandum.

7.0 Preliminary Cost Estimate

SB Barrier costs are usually based upon costs for preparatory earthwork and a cost for square foot of wall placed. Barrier earthwork requirements are not yet defined. However, a typical working platform is 40 feet in width. Assuming 3,200 lf of barrier and 3 feet of earth moving with a balanced cut and full quantity, a cost of approximately $100,000 to $150,000 would be typical. Unit costs for barrier construction are based upon several factors. Typical costs range from $4-$10/SF of placed barrier. Assuming the above parameters and average price of $7/SF, the barrier installation cost would total approximately $784,000.

The above estimate is preliminary and will change as the design develops more detail.

8.0 Proposed Construction Sequence & Approach

The final barrier construction sequence will be dependent upon the actual means and methods as well as the interdependency of other remedial components, such as the marsh excavation/treatment and groundwater extraction. However, a preliminary construction sequence is provided below for information.

1. Additional geotechnical investigation and testing
2. Contractor mobilization and sediment/erosion controls
3. Slurry mix area, mixing ponds and support facilities
4. Earthwork, working platform, grading/drainage and stabilization
5. Trench excavation, mixing and backfill
6. Final site grading/drainage and other improvements
7. Groundwater extraction system installation
8. Groundwater/barrier monitoring network installation

The sequence of the barrier and groundwater extraction will be further defined. The sequencing must consider the impoundment of the groundwater prior to groundwater extraction. This must be balanced with the logistical issues of installing any groundwater extraction components prior to or during barrier construction.

9.0 Proposed Construction Quality Assurance

Construction Quality Assurance is a continuation of the design engineer's role in the construction of a SB barrier. While the contractor will provide Construction Quality

Control of his product in the field, the inspection engineer should provide assurance testing to confirm the contractor's results.

Future design development will provide a CQA protocol for the barrier construction. It will focus on overall constructability issues and in particular on inspection and assurance testing protocol.

Attachments:
Appendix A – Draft Spec 2395

Appendix A

Specification 02395

Section 02395 - HYDRAULIC BARRIER

1. SCOPE. This section covers construction of the hydraulic barrier wall and shall include the necessary excavation, trench support using bentonite slurry, backfill preparation, backfill placement, quality control testing and other appurtenant work required to successfully construct a low permeability subsurface barrier to groundwater flow as specified below.

2. GENERAL REQUIREMENTS.

2.01. General Barrier Wall Parameters. The barrier wall shall measure approximately 3200 linear feet in length, shall vary between 20 and 55 feet in depth (height), and shall be keyed 3 feet into the underlying low permeability layer as indicated on the drawings. The barrier backfill shall consist of soil-bentonite (SB). The barrier shall measure at least 36 inches in width, shall be vertical, and be aligned as specified on the Contract Drawings for contaminant plume management as specified in the Contract Documents, Section 02200, and this specification.

2.02. Contractor Qualification. (WHAT EXPERIENCE WILL BE REQUIRED?) The Contractor shall be experienced in slurry wall construction techniques. Experience shall include at least 500,000 SF of completed soil-bentonite (SB) barrier wall construction with at least two projects completed to depths in excess of the specified depths. Experience shall also included at least 100,0000 SF of completed SCB barrier construction. In addition, the Contractor shall have on staff a registered Professional Engineer experienced in slurry wall construction and quality control testing of slurry and SB/SCB backfill. The Contractor shall provide at least this minimum level of experience to acknowledge the design and construction sequence, construct a stable slurry trench, and provide a continuous low permeability barrier to groundwater flow. The Contractor shall supply the Owner with written evidence of the required experience prior to award of the Work.

3. REFERENCES. The following references are applicable to the barrier wall construction and barrier quality control testing. Laboratory Testing procedures area described in Specification 02396.

3.01. American Society of Testing and Materials (ASTM) Standards.

C 143 Slump of Portland Cement Concrete.

C 150 Portland Cement

D 422 Particle Size Analysis of Soils.

D 698 Test for Moisture Density Relations of Soils and Soil-Aggregate Mixture, Using 5.5 lbs. Hammer and 12 in. drop.

D 2216 Laboratory Determination of Water (Moisture) Content of Soil, Rock and Soil Aggregate Mixtures.

D 4318 Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

D 4380 Standard Test Method for Density of Bentonitic Slurries.

3.02. American Petroleum Institute (API) Standard Specifications.

Code 13B Standard Procedure for Testing Drilling Fluid

Standard 13A Oil-Well Drilling Fluid Materials

3.03. Corp of Engineers Manual Series.

EM 1110-2-1906 Laboratory Soils Testing

EM 1110-2-3506 Grouting Technology

4. PRODUCTS. Contractor shall provide products as described below in quantities as required to allow successful completion of the barrier wall. Quality products shall be ensured by following established quality control protocol.

4.01. Bentonite. The Contractor shall provide a high yield untreated sodium montmorillonite (Wyoming bentonite), Federal 90 or equal, for use in slurry and any dry addition. The bentonite shall conform to the requirements set forth in API Specification 13A. The bentonite shall be protected from moisture and contact with other deleterious substances until used.

4.02. Slurry Make-up Water. Water used to make slurry shall be from a potable source and at least conform to the following criteria:

a. pH greater than or equal to 7.0;

b. Total dissolved solids not greater than 500 parts per million (ppm);

c. Oil, organics, acids, alkali, or other deleterious substances not greater than 50 ppm; and

d. Hardness less than 500 ppm.

Analysis of the make-up water sources shall be provided to the Owner prior to mixing slurry.

4.03. Additives. No additives shall be used to modify the natural slurry properties.

4.04. Trench Slurry. Contractor shall provide a fully hydrated mixture of bentonite and water proportioned to yield the following properties:

a. Filtration - 20 cc maximum by API 13B filter press test;

b. Viscosity - Minimum of 40 seconds Marsh Funnel at 65 degrees F;

c. Sand Content- Maximum of 15 percent based upon samples from the trench;

d. Density - 70 to 85 pcf as required to maintain trench stability and allow backfill placement; and

e. Conformance with all other manufacturer's recommendations.

4.05. Cement. The Contractor shall supply Type II Portland cement for preparing the SCB backfill. Cement preparation and use shall conform with ASTM C 150.

4.06. Soil-Bentonite (SB) Backfill. The Contractor shall supply soil-bentonite (SB) backfill consisting of excavated trench soils, slurry, imported fines as required, and the addition of dry bentonite. The backfill shall consist of a homogeneous blend of the ingredients. The backfill shall not contain particles greater than 2 inches in any dimension or contain fines with an organic content greater than 0.05 percent. All off-site excavated contaminated soils and sediments will be remediated to the off-site clean-up criterion of <33 ppm total COCs and pass TCLP analysis before they can be used as backfill for the off-site or on-site excavated areas. SB backfill shall conform to the following criteria:

a. Slump ranging from 4 to 6 inches;

b. Moisture content ranging from 30% to 40%;

c. Total fines (<#200 sieve) ranging from 20% to 40%;

d. Density ranging from 85 to 110 pcf, and at least 15 pcf in excess of the density of the trench slurry; and

e. Hydraulic Conductivity of 1 x 10^{-7} cm/sec or lower as measured in laboratory tests described in Specification 02396.

4.07. Soil-Cement-Bentonite (SCB) Backfill. All off-site excavated contaminated soils and sediments will be remediated to the off-site clean-up criterion of <33 ppm total COCs and pass TCLP analysis before they can be used as backfill for the off-site or on-site excavated areas. The Contractor shall supply soil-cement-bentonite (SCB) backfill consisting of material as specified for conventional SB backfill specified in 4.06 and as modified with the following criteria:

a. Slump ranging from 4-8 inches;

b. Cement content in excess of 7% by dry weight;

c. Unconfined compressive strength in excess of 40 psi as measured in laboratory tests described in Specification 02396; and

d. Hydraulic Conductivity of 5 x 10^{-7} cm/sec or lower as measured in laboratory tests described in

Specification 02396.

5. EXECUTION.

5.01. General Requirements. The Contractor shall execute all aspects of the Work to provide a quality constructed barrier wall meeting the requirements of the technical specifications and quality control procedures.

5.02. Equipment. Mechanical equipment used for trench excavation shall be of a type, design, and construction, and shall be so operated that the trench excavation bottom elevation can be controlled and that uniform trench widths and vertical sidewalls are obtained from the top of the trench to the bottom of the trench. Other Mechanical equipment used in trench excavation, mixing and backfill shall be of adequate type, design, and construction to ensure fully hydrated slurry, homogeneous backfill, uniform backfill placement, and yield a constructed product as defined in this and referenced specifications.

5.03. Working Platform. The Contractor shall construct an earthen berm to function as a working platform for construction of the barrier wall. The working platform shall be constructed to the lines and grades as defined on the Contract Drawings and to the requirements as outlined in the Earthfills and Embankments Section of Earthwork Specification 02200. Crane mats or timbering shall be used on the working surface to prevent rutting and sloughing. The working platform shall be graded to drain into the slurry trench to limit spillage.

5.04. Trench Excavation and Sequence. Trench excavation, and subsequent backfilling, shall first be completed in designated SCB areas identified below:

Station Range	
1+50 to 4+65	(range of full depth SCB backfill)
10+30 to 11+75	(range of full depth SCB backfill)

Subsequent trench shall be excavated starting at Station 4+65 and proceed in a clockwise direction. The trench shall be excavated from the top of the platform, measure at least 36 inches in width, be keyed 3 feet into the underlying low permeability layer, and be free and clear of any obstructions prior to backfill placement. Trench verticality shall be maintained. Trench excavation shall be performed so as not to spill slurry into any adjacent watercourse or drainage way. SCB excavation ranges shall be completed such that subsequent SCB backfill shall be full height within the specified ranges. Infill excavation for SB construction shall be performed to create a continuous barrier and uniform transition between SB and SCB backfill.

5.05. Trench Stability. The Contractor shall maintain trench stability by adjusting slurry head and density within the ranges of the parameters specified herein. Sufficient slurry shall be readily available to adjust trench slurry heights to respond to rising groundwater or adjacent high surface water conditions. Equipment live loading, other than excavation and backfill equipment, shall not be allowed adjacent to the open trench. Stockpile materials shall be placed a sufficient distance from the trench to maintain stability. Excavation equipment shall not be allowed to track back over the open trench.

5.06. Trench Slurry Sampling and Testing. Contractor shall perform periodic quality control testing of both the fully hydrated slurry before use in the trench and during use in the trench. Contractor shall provide experienced personnel to collect samples and perform such tests as required by the reference standards. Tests shall be performed at the site by the Contractor or the Contractor's independent laboratory as outlined below:

Test	Frequency
Viscosity	
As Mixed	Minimum of twice daily (minimum).
In Trench	At 10 feet below trench top, 5 feet above the trench bottom, and at an intermediate depth taken on 75 feet intervals; minimum of twice daily (start and end of day).
Filtrate Loss	
As Mixed	Minimum of 3 times weekly.
In Trench	At 5 feet above the trench bottom; minimum of twice daily (start and end of day).
Unit Weight	
In Trench	At 10 feet below trench top, 5 feet above the trench bottom, and at an intermediate depth taken on 75 feet intervals; minimum of twice daily (start and end of day).

Contractor shall summarize and report results of testing to the Engineer on a daily basis.

5.07. Trench Limits. The barrier wall alignment shall be within one foot (± 6 inches) of the alignment as shown on the Contract Drawings. Verticality of the trench shall be maintained with an allowance for variations up to 2 percent of the total depth.

5.08. Trench Bottom. The trench shall be excavated to the target depth representing, a 3 foot key into the low permeability layer as shown on the Contract Drawings. The Contractor shall collect bottom samples for inspection by the Owner to confirm the presence and depth of the low permeability layer prior to backfilling. Sample collection methods shall be acceptable to the Owner. Bottom samples shall be collected by the Contractor at 20 foot intervals to confirm the target depth and trench bottom.

5.09. Backfill Mixing. Backfill shall be thoroughly mixed in the required proportions using dozers, scrapers, paddle mixers, diskers, or other suitable equipment to achieve the performance requirements of the specifications. Mixing can be performed adjacent to the trench (site interior)

or at a central mixing location in the site interior as specified by the Contractor and approved by the Owner. Mixing operations shall produce a homogeneous backfill. No backfill shall be mixed or placed during freezing temperatures or on frozen surfaces, nor shall frozen materials, snow, or ice be placed in any backfill. Backfill mixing shall be considered complete when backfill meets design and performance standards immediately prior to placement and is approved by the Owner based upon testing requirements as defined in Specification 02396. Approved backfill shall not be modified prior to placement.

5.10. Backfill Placement. Backfill shall be placed only when the trench bottom and existing backfill slope have been approved by the Owner. No backfill shall be allowed to free-fall in the trench slurry. Contractor shall utilize a lead-in trench, end-stop, and/or clamshell placement as approved by the Owner to initiate backfill placement and eliminate free-fall. After initial placement, the Contractor shall place the approved backfill and push the previously placed backfill to move down the slope and remain free of slurry pockets, sloughing, or other deleterious material. In a continuous open trench, the toe of the backfill slope shall be maintained between 50 and 125 feet from the toe of the trench excavation. The Contractor shall use a suitable guide trough and splash guards to control placement and minimize spillage.

5.11. Confirmation Sampling and Sounding. The excavated trench bottom shall be confirmed on a 20 foot interval as defined in Section 5.08. The backfill slope and exposed trench bottom shall be sounded for elevation by the Contractor to confirm stable slopes and absence of undesirable material. Such soundings shall be made frequently and immediately prior to backfilling for approval by the Owner. At a minimum the slope and bottom shall be sounded at least every 20 feet as outlined below:

a. during the start of each work day;

b. immediately prior to backfill placement in the area to be filled; and

c. at the completion of each work day.

Confirmation soundings shall be provided to the Owner upon collection and recorded on trench cross sections available to the Owner.

Sampling to determine backfill properties shall be performed as defined by this Specification and Specification 02396.

5.12. Bottom Cleaning. The approved trench bottom shall remain free and clear of sediment buildup. The Contractor shall clean the trench bottom if sediment buildup, as determined by soundings, rises above a limit of 6 inches higher than the approved trench bottom elevation.

5.13. Trench Closure. Trench closure shall be made with suitable overlap to ensure continuity of the barrier backfill over the entire trench depth. The closure detail is dependent upon trench initiation and shall be submitted to the Owner for approval.

5.14. Confirmation Borings. Borings shall be drilled through the completed backfilled trench to collect confirmation samples. Borings shall be completed on 250 foot centers with one sample~~s~~

collected for every five feet of drilling. Drilling, sampling, and reporting shall be performed according to Specification 02670.

5.15. Settlement Monitoring. The Contractor shall provide, install, and monitor 7 settlement plates to be placed on approximately 300 foot centers around the circumference of and directly above the barrier wall. Settlement plates shall consist plywood bases with galvanized pipe and be of a design acceptable to the Engineer. Plates shall be placed prior to placement of the Interim Clay Cap. Monitoring shall include an initial survey of horizontal and vertical positions, weekly elevation measurements for the first three months and monthly elevation measurements for the first year. Results shall be reported to the Owner after each reading in a format acceptable to the Owner.

5.16. Interim Clay Cap. The Contractor shall place a 2 foot thick clay cap over the completed backfilled trench as shown on the Contract Drawings. The exposed backfill shall not be subjected to the elements for greater than two days. Suitable temporary cover material shall be placed over the backfill if site grading does not allow prompt placement of the interim clay cap. The clay cap shall be placed after the working platform is cut back as needed for site excavation and grading, and after initial backfill settlement occurs, as determined by the Engineer.
The clay cap shall be placed at a moisture content of at least two (2) percent above optimum. Compaction shall be carried out as described in the Earthwork section. The first lift of clay shall be placed in a 12 inch lift with the succeeding lifts placed as described in the Earthwork Section 02200. During the period of ten (10) working days after initial compaction, the area above the barrier wall shall be recompacted to develop and expose any possible depression in areas and to speed up settlement. If any sink should develop within the backfilled area, it shall be repaired by placing and compacting additional impervious material.

5.17. Establishing Flow Zones. After completion of construction of onsite structures and backfill of onsite excavations, the Contractor shall excavate portions of the hydraulic barrier to reestablish groundwater flow between the containment area and surrounding area. The Contractor shall replace the hydraulic barrier backfill between Stations 19+50 and 21+00 to 782 FT AMSL with permeable sand and gravel.

The width of excavation shall include at a minimum the width of the backfill plus an additional four (4) feet on both sides of the excavation. The adjacent completed barrier wall shall be protected with sheeting or other means acceptable to the Engineer during excavation. Excavation shall conform to the general procedures as defined in Earthwork Specification 02200. Alternate trenching methods, including biopolymer methods will be considered by the Engineer. Upon satisfactory completion and confirmation of excavation, the flow zone shall be backfilled with SP, GP or GW soils as made available by the Contractor from other onsite excavations. The granular backfill material shall be maintained free and clear of deleterious material and be placed in such a manner to avoid mixing with additional fines and segregation of granular material.

The Contractor shall submit methods and procedures of construction to the Engineer for approval prior to replacing portions of the barrier wall with permeable material.

6. DISPOSAL OF EXCESS EXCAVATED MATERIALS. Insofar as possible, suitable excavated materials shall be used in the trench backfill and for fills to raise the site to final

constructed elevations. Unsuitable material shall be disposed offsite consistent with Specifications 01605 and 01606.

6.01. Disposal of Bentonite Slurry. The Contractor shall sample the bentonite slurry at the completion of backfilling prior to final displacement consistent with Specification 01605 for the Owner's review. Upon approval the final slurry shall be displaced to a suitable location on the site and mixed with Type II Portland Cement, or other acceptable stabilizing additives, to achieve physical soil properties for use onsite as approved by the Owner.

7. DRAINAGE MAINTENANCE. Surface drainage shall not be obstructed longer than necessary. Controlling and maintaining surface drainage shall be the responsibility of the Contractor throughout the construction.

8. QUALITY CONTROL. The Contractor shall provide adequate construction quality control to ensure the constructed product meets or exceeds the design and performance criteria of the Contract Documents. Quality control shall be performed by the Contractor's laboratory or an independent third party laboratory secured by the Contractor and experienced in such testing. Quality control testing procedures are as defined herein and in Specification 02396.

The Contractor shall maintain neat and orderly quality control documentation and shall make such information available to the Owner upon request.

9. QUALITY ASSURANCE. The Owner will perform quality assurance inspection and testing as deemed necessary. The Contractor shall assist the Owner during sample collection for such testing. Results of such testing will be available to the Contractor upon request.

10. SUBSURFACE CONDITIONS. The subsurface conditions along the barrier wall alignment as shown on the contract drawings are based upon interpretation of discrete boring locations (located on approximately 150-200 foot centers, within approximately 50 feet of the barrier centerline). The Owner is not responsible for differences between the interpretation and actual stratigraphy. The Contractor shall perform additional borings as shown on the Contract Drawings and defined below:

		Location	
Boring	**Depth**	**North**	**East**
HB-7	70 feet		
HB-8	70 feet		

The Contractor may choose to complete additional borings along the alignment prior to barrier construction. All drilling shall conform to Specification 02670 and be logged by a qualified geologist or geotechnical engineer retained by the Contractor. Delaware Department of Natural Resources' and Environmental Control (DNREC) Boring Logs shall be used to record all pertinent data and shall be submitted to the DNREC, and a copy forwarded to the Engineer.

11. SURVEYING. Surveying for elevation control for barrier construction shall conform to surveying requirements outlined in the Contract Documents. In addition to intermediate elevations and settlement monitoring specified herein, the Contractor is required to provide a final

as-built survey of the barrier centerline and surface elevation.

12. Drawings and Data. Detailed drawings and data shall be submitted to the Owner in accordance with the Submittals Section.

12.01. Submit Prior to Award of Work. Contractor shall supply qualifications and experience as specified herein.

12.02. Submit Prior to Construction. Contractor shall submit product data and sources of material. Contractor shall submit a plan and description of the Contractor's design of site operations including location of slurry ponds, bentonite storage, backfill mixing, and equipment laydown. The description shall discuss methods and procedures to be used to comply with the specifications. Contractor shall submit proposed methods and procedures for construction of flow zones in the completed barrier walls as specified herein.

The Contractor shall determine and test the SCB backfill design mix for approval by the Engineer. Testing shall be performed as outlined in Specification 02396 with sufficient strength and permeability testing to demonstrate compliance with the technical requirements. At a minimum, two tests shall be performed; one with 7% cement by weight and another with 12% cement by weight. Proposed testing methods shall be submitted to the Engineer for approval prior to testing. Test results shall be submitted to the Engineer prior to construction.

12.03. Submit During Construction. Contractor shall provide slurry tests, backfill monitoring, settlement monitoring, and other requirements specified herein.

End of Section